



How to Demonstrate Microgravity in your Classroom

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Contents

- Physics of microgravity
- Where can you find microgravity?
- Microgravity Educator's Resources
- Microgravity Demonstrator Devices
- Hands-on Time

MICRO-*gravity*

Physics of microgravity

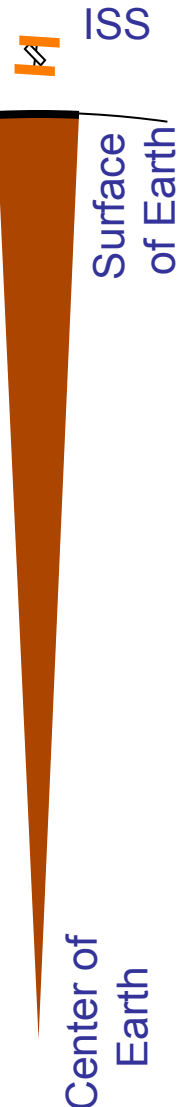
- Microgravity is due to a free-fall condition
 - Gravitational **effects** are due to restraining forces which stop an item from falling
 - The floor stops you from falling with a force on your feet.
 - A bathroom scale shows this force as your weight.
 - In free-fall, restraining forces are drastically reduced
 - Everything is falling at the same rate.
 - A person falling with a bathroom scale, would not ‘weigh’ anything as they fall.

REMEMBER, IT'S ALL RELATIVE

gravity - MICRO

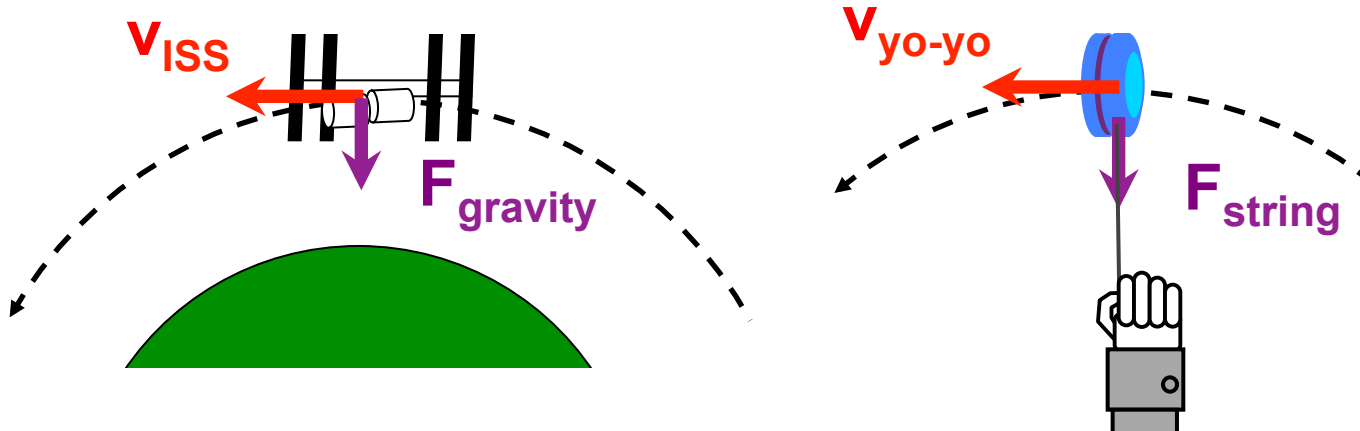
Physics of microgravity

- Microgravity is **NOT** zero-gravity nor 0-g
 - At sea-level, we are about 6400 km (4000 mi) from the center of the Earth
 - gravitational acceleration is 9.8 m/s^2 (a.k.a. 1-g)
 - At the International Space Station (ISS) altitude of 400 km (250 mi), they are 6800 km (4250 mi) from the center of the Earth - just a little further away!
 - gravitational acceleration at ISS altitudes is about 90% of 1-g or about 8.8 m/s^2
- So why do astronauts ‘float’ around on the ISS?
 - The astronauts are just falling with the ISS vehicle
 - Keep reading to find out about ‘falling with style’ !



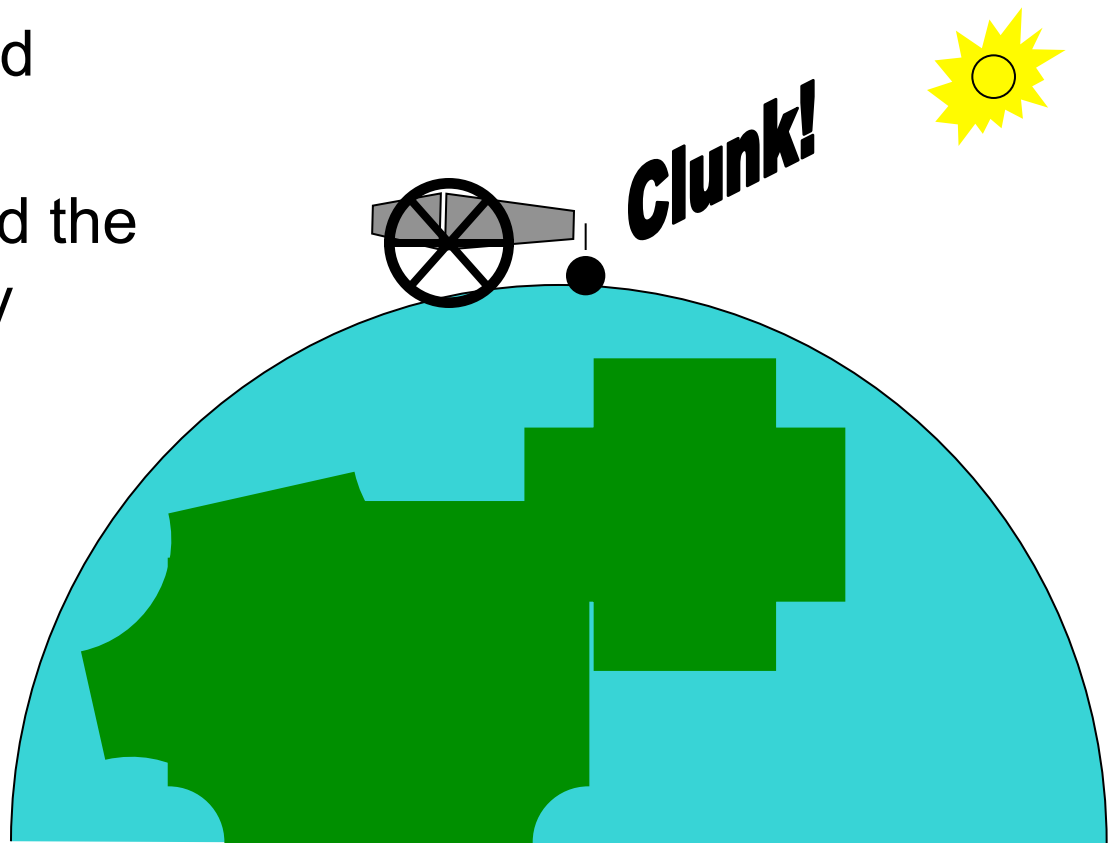
Physics of microgravity

- It is **NOT** a balance of forces
 - The gravitational force acts on the ISS and its contents to maintain a circular orbit
 - Like swinging a yo-yo around in a circle
 - String acts as gravity
 - If it were 0-g, the ISS would sail off into space!
 - As the yo-yo does when you let go of the string
 - In classroom, demonstrate with a foam yo-yo or a soft ball on a string



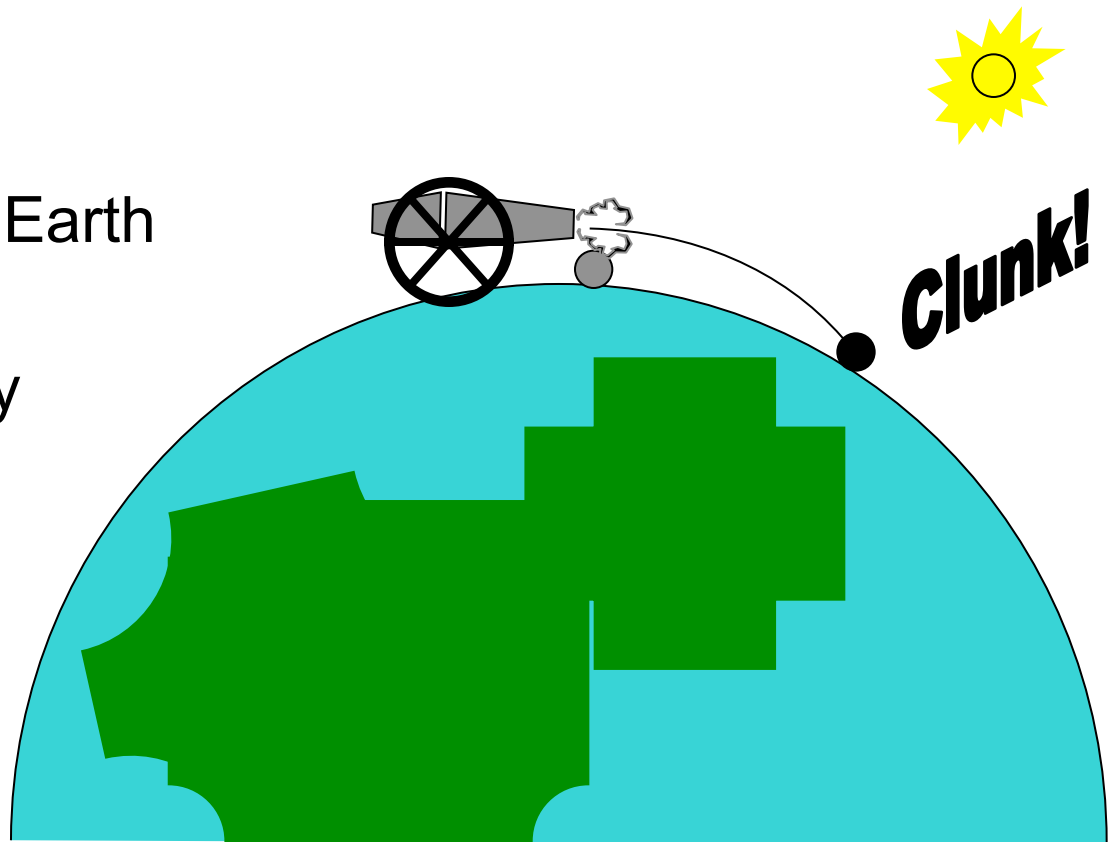
Falling Straight Down

- Cannonball dropped from end of barrel
- Falls straight toward the Earth due to gravity



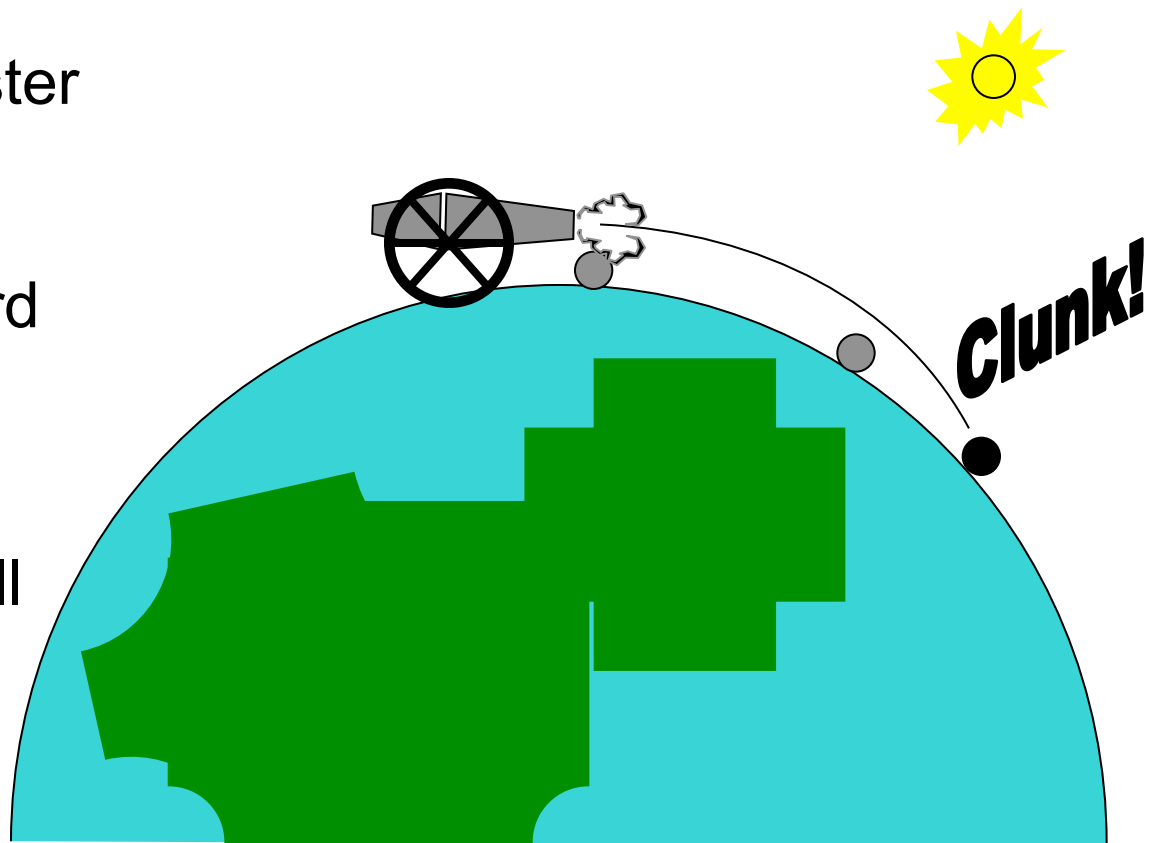
Falling Sideways

- Cannonball shot horizontally
- Curves toward the Earth due to gravity
- Hits the Earth away from the cannon



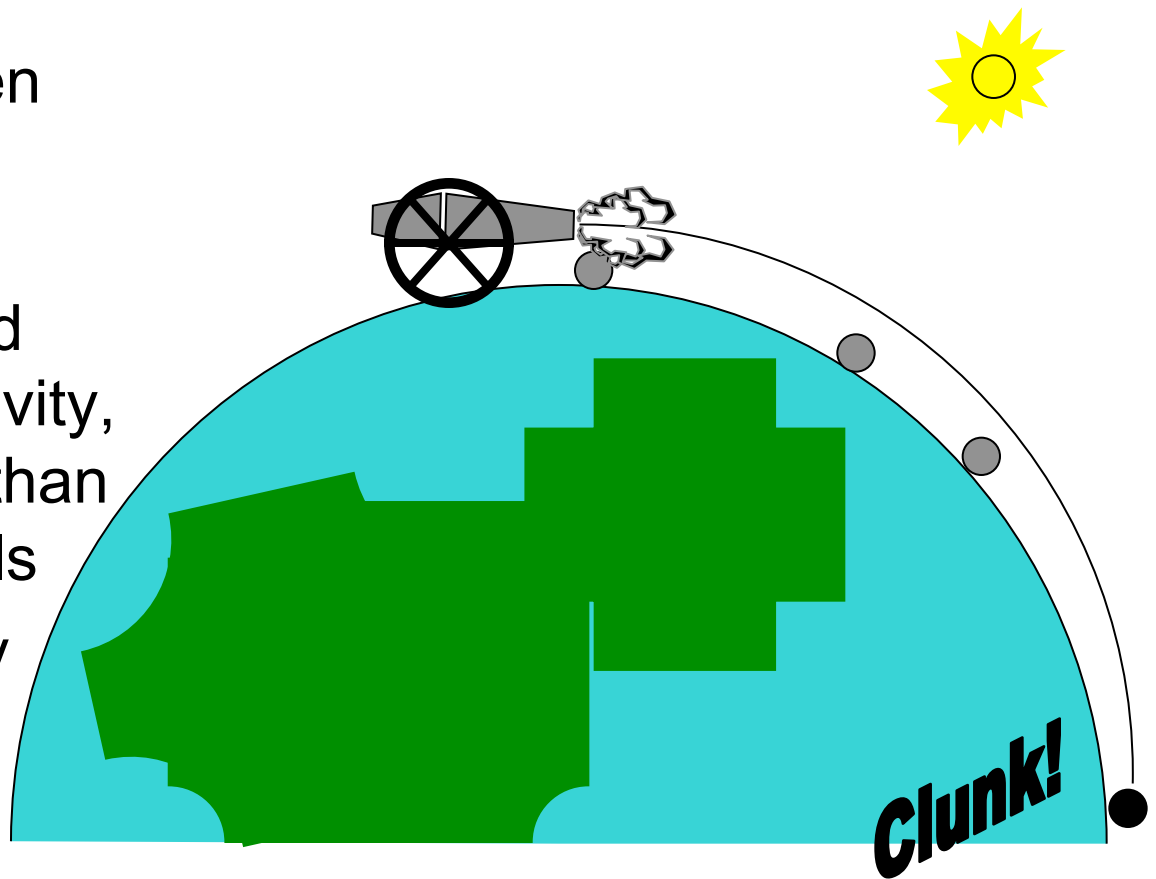
Falling Sideways

- Cannonball shot horizontally, but faster than the previous cannonball
- It also curves toward the Earth due to gravity, but more gradually than the previous cannonball
- Lands farther away from cannon



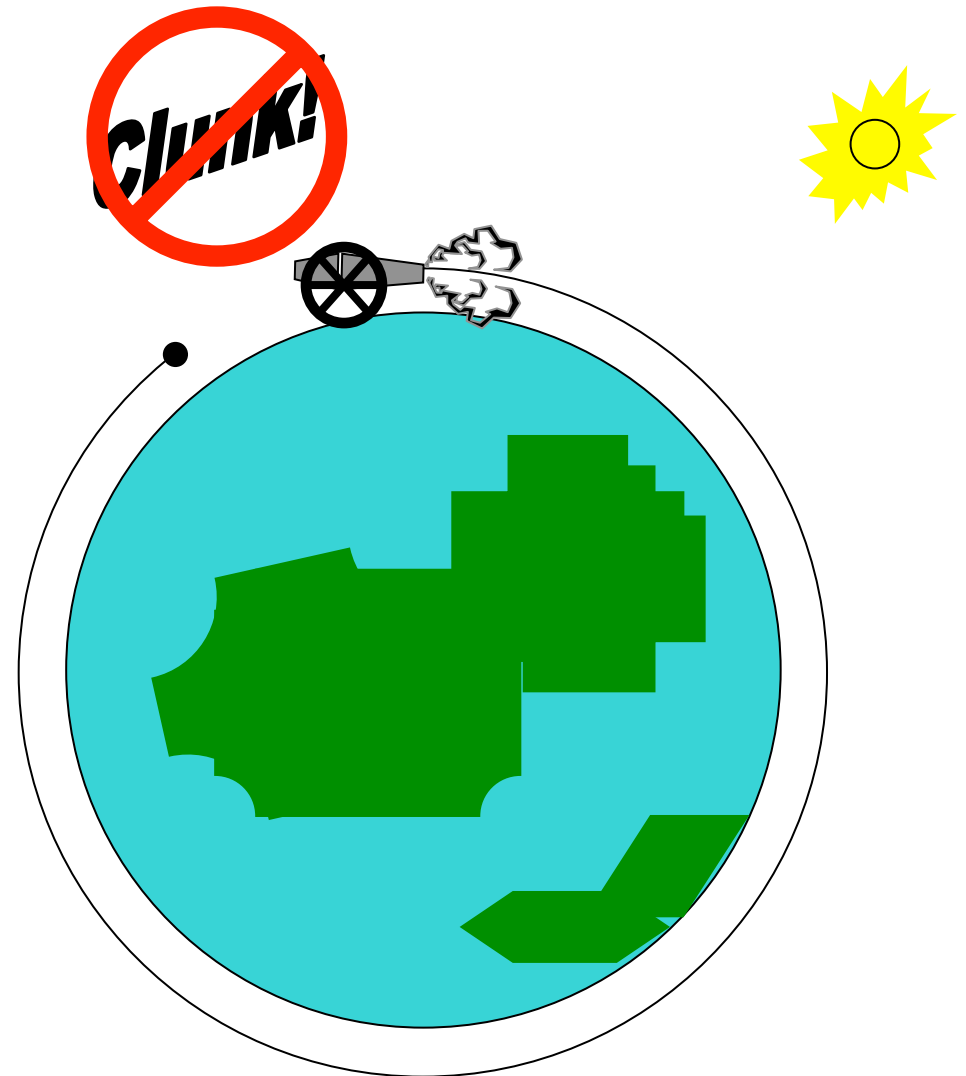
Falling Sideways

- Cannonball shot horizontally, but even faster than previous cannonball
- It also curves toward the Earth due to gravity, but more gradually than previous cannonballs
- Lands farthest away from cannon



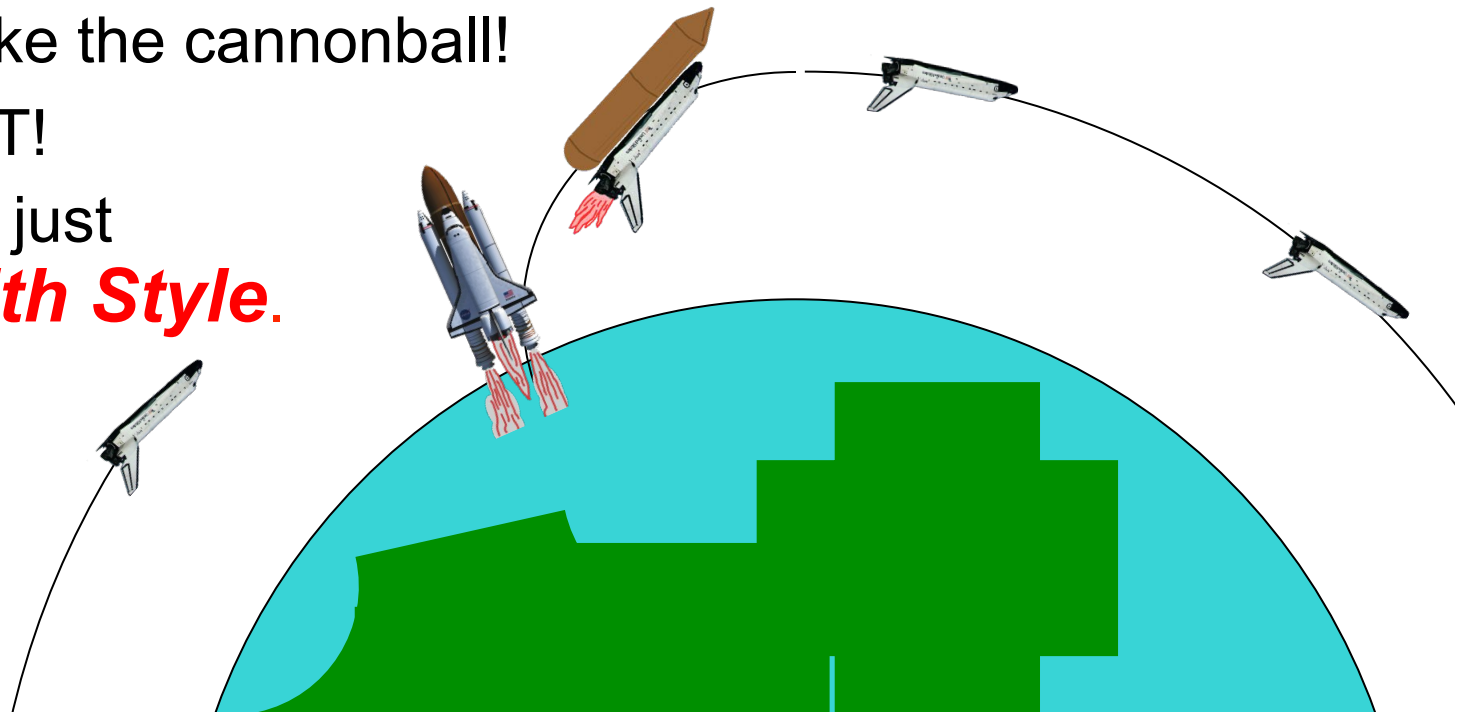
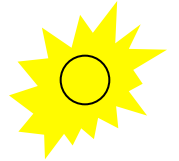
Falling with Style

- Cannonball shot horizontally at just the right speed falls with the curvature of the Earth
- Speed is about 30,000 km/hr
- It curves toward the Earth due to gravity, but, so gradually, it falls around the Earth
- Voila, ORBIT!
- It is really just ***Falling with Style.***



Launching with Style

- The Space Shuttle took off vertically
- Gradually, as it climbed, it developed the proper orbital speed sideways
- When the engines stopped, the Shuttle was falling with the curvature of the Earth, just like the cannonball!
- Voila, ORBIT!
- Orbit is also just ***Falling with Style.***



Floating Around in the ISS

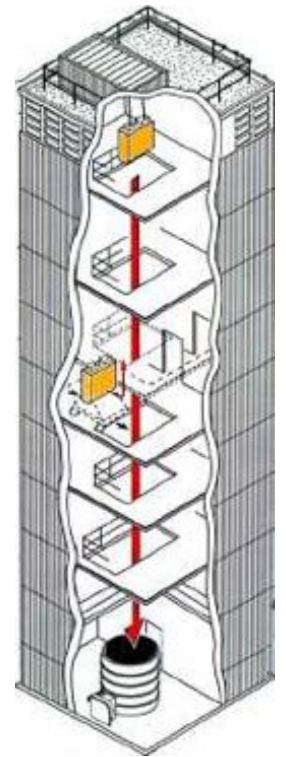
- The crew members “float” around inside the ISS because they are falling around the Earth along with the ISS.
- The crew members, the ISS vehicle, experiments, food - everything - is falling together.
- Just like dropping two balls at the same time, they both fall to the floor side-by-side.

Falling Straight Down and Falling with Style

- Conceptually the same - accelerating toward the center of the Earth
- Horizontal velocity makes the difference
 - Earth-orbiting horizontal speed is about 30,000 km/hr (18,000 mph)
 - Drop tower horizontal speed is 0 km/hr (0 mph)
- So, drop towers can provide free-fall (a.k.a. microgravity conditions) just as ISS does
- Falling with style may be demonstrated in your classroom by dropping a foam ball straight down and then throwing it sideways faster and faster

Where can you find microgravity?

- Microgravity exists ...
 - ... en route to the moon while coasting.
 - ... in orbit on the ISS.
 - ... in sounding rockets (into space).
 - ... in an airplane flying a parabolic path.
 - ... in drop towers as ground-based labs.
 - ... in your **classroom**.



*2.2 Second Drop Tower
at NASA Glenn*

Microgravity On-line Educator Resources

- Loads of **free** information on NASA web pages

<http://www.nasa.gov/audience/foreducators/index.html>
or: <http://tinyurl.com/NASA-Educators>

- NASA Educational Materials

<http://tinyurl.com/NASA-EduMaterial>

- What is Microgravity?

<http://tinyurl.com/WhatIsUG>

- Microgravity Teachers Guide

<http://tinyurl.com/MTGuide>

- NASA Space Place

<http://tinyurl.com/SP-Orbits2>

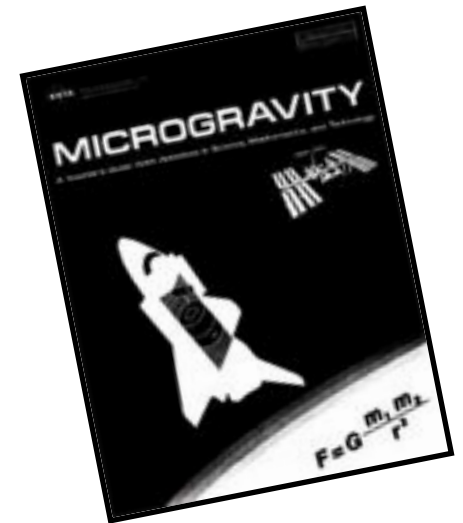
(Orbital cannonballs!)

<http://tinyurl.com/SP-Gravity>

(What is Gravity?)

<http://tinyurl.com/SP-Kids2>

(SpacePlace for Kids)



URLs can be case sensitive!
"G" is not "g" - be careful!

Microgravity Educator Resources

- Additional Items -



- NASA educational products available for **free**
 - Contact a local NASA **Educator Resource Center (ERC)** from an on-line list:
 - <http://tinyurl.com/ListERC>
- NASA educational products available for a nominal fee (\$\$)
 - **Central Operation of Resources for Educators (CORE)** catalog has more than 200 NASA produced videocassette, slide, and CD-ROM programs available for a minimal charge.
 - <http://tinyurl.com/CORE-home>
- Informal Web Page of Amusement Park Physics products
<http://tinyurl.com/APPD-info>
 - Acceleration match game for amusement park rides
 - NASA drop tower height comparison with amusement park rides
 - NASA microgravity aircraft comparison with roller coasters
 - Middle school teachers guide
 - *Amusement Park Physics with a NASA Twist*

Microgravity Demonstration Devices

- Simple -

- Incredibly Cheap Free Fall Demonstrator
- Astronaut in a bottle
- Leaky water bottle
- Balloon popper

Incredibly Cheap Free Fall Demonstrator



- Equipment
 - Cardboard box (approx. 12" x 12" x 6" deep)
 - Two character figures popular with kids
 - Weight (e.g. heavy plastic, large eraser, small wrench [as shown])
 - Rubber bands (several, as needed)
 - White paper
- Setup
 - Fold top flaps of box inward or cut them off so box is 'open'.
 - Turn box on side as shown.
 - Tape or glue paper on back of box for better visibility.
 - Tape or hot glue the weight below one of the figures.
 - Attach the rubber band between the top of the weighted figure and the box top.
 - Adjust the length so the rubber band is stretched but the figure is resting near the bottom of the box (may need to use a couple of rubber bands in a chain to get the length right).
- Procedure
 - Stand the loose figure on the box bottom next to the weighted figure.
 - Drop the box into something soft (e.g. pillow).
- Observations when the box is falling:
 - The loose figure will continue to stand on the bottom, it is falling with the box.
 - The second figure will snap upwards due to the force of the stretched rubber band.
- Why?
 - Initially, gravity was stretching the rubber band against the force that kept the box from falling
 - When the box was released to fall, that restraining force was gone so the rubber band shrunk, pulling the figure upwards in the box.
 - The loose figure simply falls with the box.

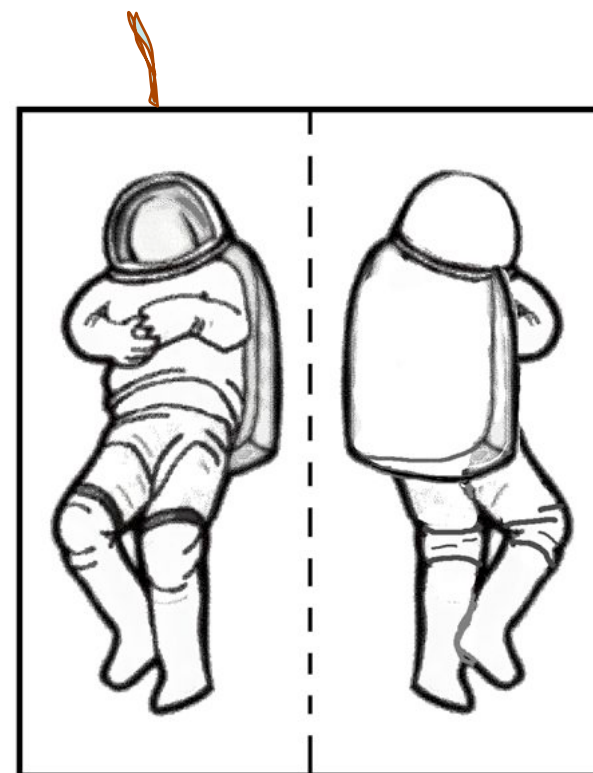
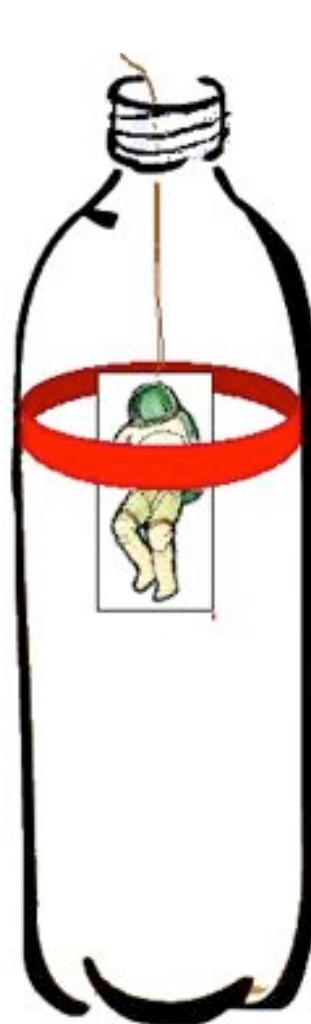




Astronaut in a bottle

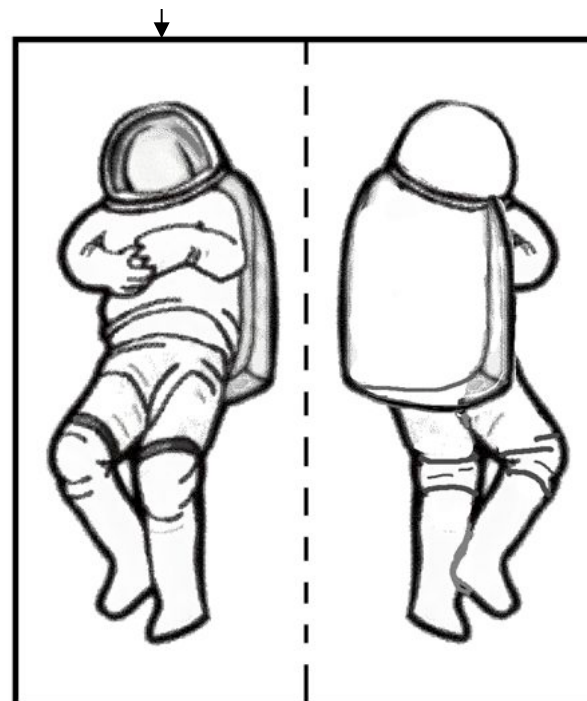
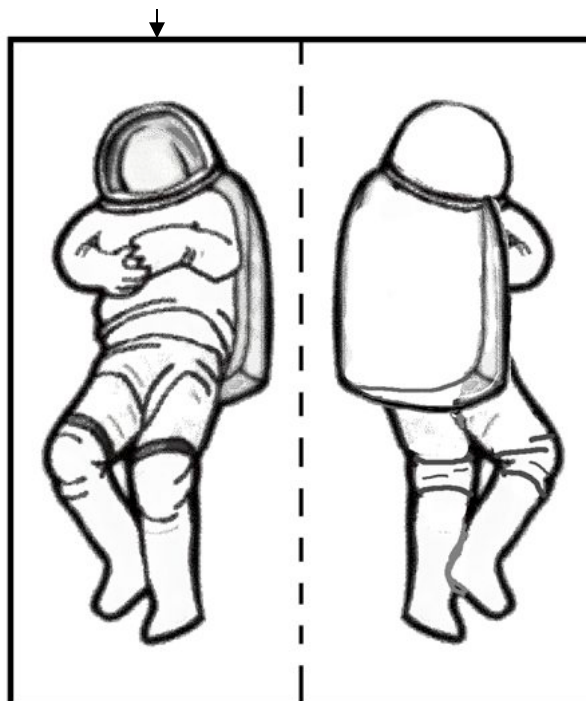
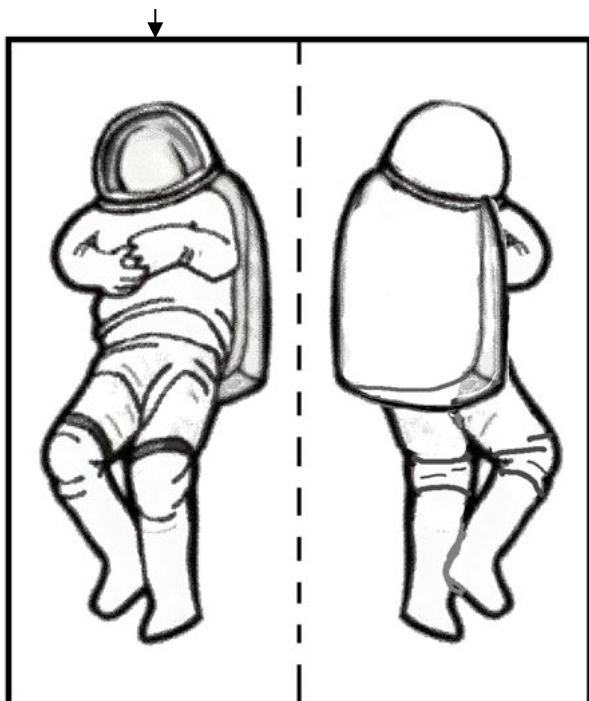
Free-fall & 'weightless' demo

- Equipment
 - 2-liter clear plastic bottle
 - Colored tape or marker
 - Cardboard astronaut
 - String
- Procedure
 - Draw broad stripe on bottle with tape or marker
 - Attach string to cardboard astronaut
 - Hold string in neck of bottle with a finger so astronaut is even with the line (as shown)
 - First, release just the string and hold the bottle
 - Observe astronaut falling to bottle bottom
 - Then, reset and release string and bottle together
 - Observe astronaut falling with bottle during drop
- Astronaut is 'floating' in falling bottle just as real astronauts 'float' in the International Space Station (ISS)
 - Both cases are examples of free-fall
 - The ISS, though, is going $30,000 \text{ km/hr}$ sideways while it falls around the Earth!

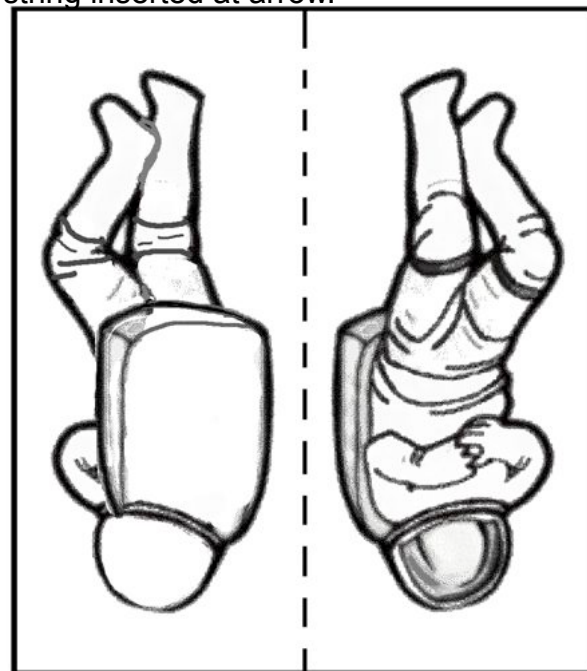
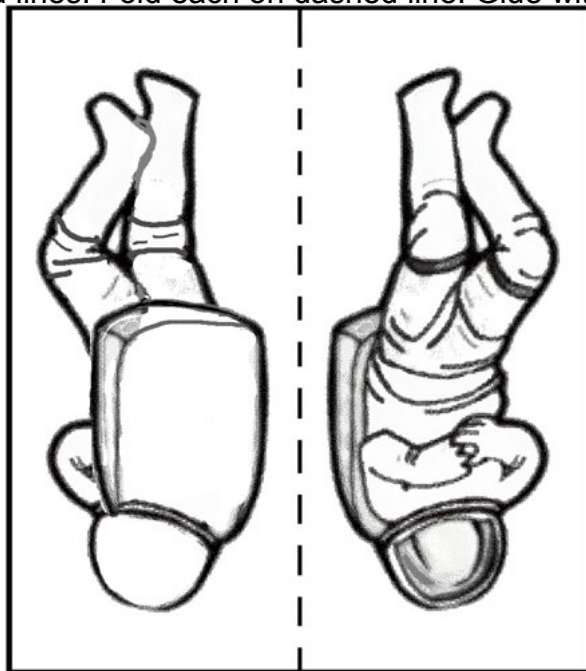
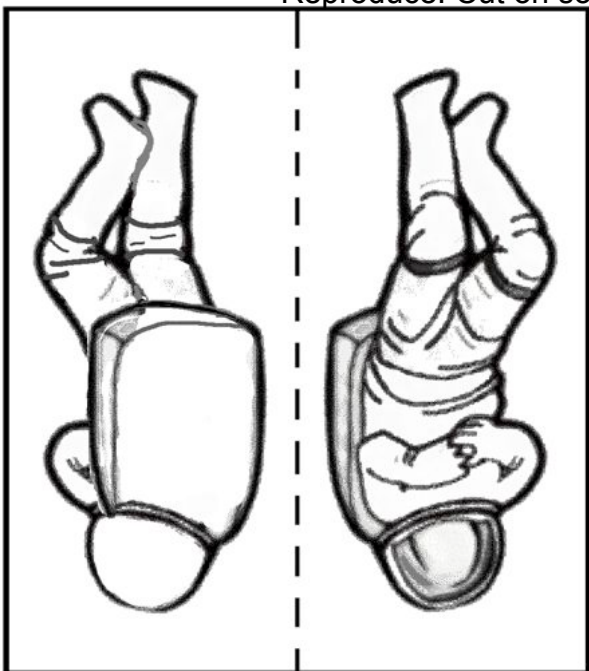


Cut out, fold, and paste with end of string inside.

***For additional copies,
photocopy next page.***



Reproduce. Cut on solid lines. Fold each on dashed line. Glue with string inserted at arrow.



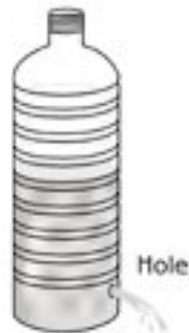
Leaky water bottle

Free-fall & 'weightless' demo



Before drop/toss

Clear plastic bottle, small hole at bottom, filled with water, and no cap.



1. Why does the water flow out the hole before the bottle is dropped or tossed?

2. When the water bottle is *dropped* the flow of water:

- a) becomes faster
- b) stays the same
- c) becomes slower
- d) stops



Explain why the flow of water behaves this way.

4. What is meant by 'free-fall'?

3. When the water bottle is *tossed upward* the flow of water:

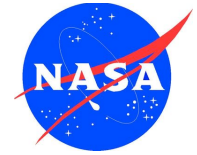
- a) becomes faster
- b) stays the same
- c) becomes slower
- d) stops



Explain why the flow of water behaves this way.

5. What do freely falling objects experience?

Leaky water bottle - explanation



▪Why does the water flow out of the hole before the bottle is dropped or tossed?

A hand exerts a force on the bottle to stop it from falling. The rigid bottle then exerts a force on the water to stop it from falling. Being a liquid, the water squirts through the hole due to the gravity force pulling it downward.

▪When the water bottle is dropped, the flow of water: (d) stops

▪Explain why the flow of water behaves this way.

The water is falling due to gravity so it doesn't need to 'sneak' out the hole to fall. The bottle is falling with the water and doesn't exert a force on the water.

▪What is meant by "free-fall"?

An object is in free fall when it is accelerating at the rate of gravitational acceleration and without any external retarding or accelerating forces.

▪When the bottle is tossed upward, the flow of water: (d) stops

(The toss should be smooth so as to not spin or tumble the bottle.)

▪Explain why the flow of water behaves this way.

Again, once the bottle and water are free from the hand, they are in free-fall. In this case, there is an initial velocity upwards, but both the bottle and water are falling toward the Earth. (For the short time that the hand accelerates the bottle and water upward, the water flowing out *does* increase, but only until the hand releases the bottle.)

▪What do freely falling objects experience?

The force we feel as weight is the retarding force of a floor or chair to keep us from falling. A free-falling object does not have such a retarding force, so it feels 'weightless'.

Try it yourself!

Instructions: (It is best to try this outdoors)

1. Have an adult, with a knife or awl, poke a small circular hole in the side of the bottle, near the bottom.
2. Cover the hole with your thumb and fill the bottle with water.
3. Uncover the hole and the water streams out (with the cap off).
4. Before the water runs out, drop the bottle. Watch whether the water comes out faster, slower, or the same.
5. Refill the bottle, uncover the hole, and toss the bottle straight upward or upward at an angle (while keeping the bottle upright). Again watch the water stream.

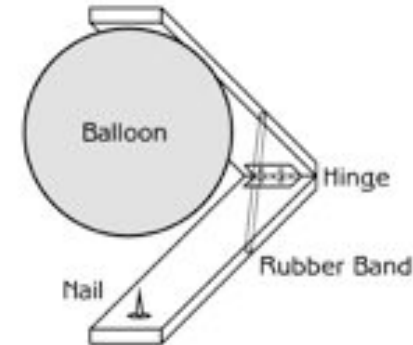
Balloon popper



1. Identify the forces acting on the Balloon Buster just before it is dropped.

- 1) _____
- 2) _____
- 3) _____
- 4) _____
- 5) _____

Hint: There may be less than five forces.



2. Air resistance has what kind of effect on the falling Balloon Buster?

- a) Large
- b) Medium
- c) Small
- d) Almost none

3. When or where in the fall does the balloon pop?

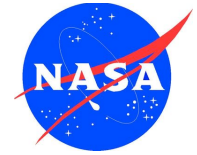
- a) Right after it is released
- b) Half way down
- c) When it hits the ground or floor
- d) The balloon does not pop

4. While it is falling, what force causes the Balloon Buster to close?

5. Explain why the Balloon Buster does not close before it is dropped.

See additional construction instructions on SEEC microgravity session web site!

Balloon popper - explanation



- **Identify the forces acting on the Balloon Buster just before it is dropped.**

A hand exerts a force on the top bar to keep the Balloon Buster from falling. Gravitational attraction is exerting a force on the entire apparatus and balloon, pulling them downward. The gravitation force on the lower arm causes it to stretch the rubber band, generating an internal force, which tends to hold the lower arm up.

- **Air resistance has what kind of effect on the falling Balloon Buster?**

- (d) almost none because the balloon pops before the apparatus gains any significant speed through the air

- **When or where in the fall does the balloon pop?**

- (a) Right after it is released

The rubber band exerts an internal force which pulls the two arms together. Without the retarding force of the hand holding the upper arm, the rubber band snaps the two arms together, popping the balloon.

- **While it is falling, what force causes the Balloon Buster to close?**

The internal force caused by the stretched rubber band.

- **Explain why the Balloon Buster does not close before it is dropped.**

The hand holds the upper arm while gravity pulls the lower arm downward.

Try it yourself!

- **Build your own Balloon Buster**

The main framework is made from two pieces of hardwood (to withstand repeated drops), a hinge, and two screws. Each hardwood piece is about 5 cm by 2 cm and about 30 cm long. Pins or sharp nails can be held in place with a rubber lab stopper. The balloon neck is held in place with a smooth V-shaped slot or a spring-type clothes pin. A screw is put in the side of the upper and lower arms but not screwed in flush with the wood to provide a place for the rubber band to be inserted. The rubber band should be of sufficient strength when stretched to nearly balance the weight of the lower arm before dropping.

Microgravity Demonstration Devices

- Movies -

- Movies
 - Water balloon on DC-9 parabolic-flight aircraft
 - On-line at:
<http://tinyurl.com/NASA-WB-1>
or: <http://spaceflightsystems.grc.nasa.gov/WaterBalloon/>
 - Helium balloon in 2.2 Second Drop Tower at NASA Glenn
 - On-line YouTube video at:
<http://tinyurl.com/ugHeBallon>
 - Or <http://www.youtube.com/watch?v=0NZSeTXDj6I>
 - On-orbit crew videos with toys
 - Available in DVD format from ERC and/or CORE
 - Examples:
 - International Toys in Space
 - Toys in Space II
 - Also available is a Toys in Space Kit to go with the above programs

Microgravity Demonstration Devices

- Moderately complicated -

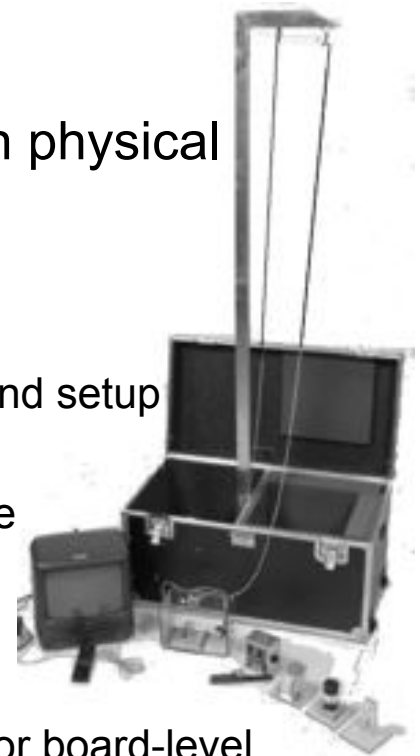
- Accelerometer & data logger
 - Use in the classroom and at amusement park
 - Toss and catch accelerometer - low-g during free fall
 - Attach accelerometer to various drop containers
 - Observe low-g levels for different frontal areas, such as:
 - heavy text book vs. horizontal cardboard
 - Broom handle (straight down) vs. large plywood sheet (sideways)
 - Investigate terminal velocity for falling in air
 - Amusement park rides (see informal physics day web site)
<http://tinyurl.com/APPD-info2>
or: spaceflight systems.grc.nasa.gov/outreach/appd/appd_resources.html
 - Free fall conditions (i.e. low-g) on some roller coasters
 - Variety of other accelerations may be observed (e.g. linear, centripetal)
 - Use it safely with positive restraint (vest or waist pack)
 - Add barometer for height indication of amusement park rides
 - Example product:
 - Vernier LabPro with 3-axis accelerometer
- Note: use of trade name does not imply endorsement by NASA. --

Drop into something soft!!

Microgravity Demonstration Devices

- Advanced -

- Mini drop tower demonstrates microgravity effects on physical science
- Versions
 - Original NASA Glenn version
 - Foot-locker size, rugged design for easy transportation and setup
 - Wireless version
 - Less-expensive design with no wires or ropes on carriage
 - Classroom concept
 - Simple & inexpensive for fixed location
 - Plastic storage box with camera mounted inside
 - Camera options: modern digital camera (w/video mode) or board-level electronic camera
 - May use existing resources for video recording and playback
 - Classroom VCR/TV and/or computers
 - VCR should have quality slow-motion or single frame motion
 - Computer should have video input software, preferably with editing, titling and export functions



Microgravity Demonstration Devices

- (continued) -

- Resources:

- Original NASA Microgravity Demonstrator

<http://tinyurl.com/MiniDrop-D> ←Description

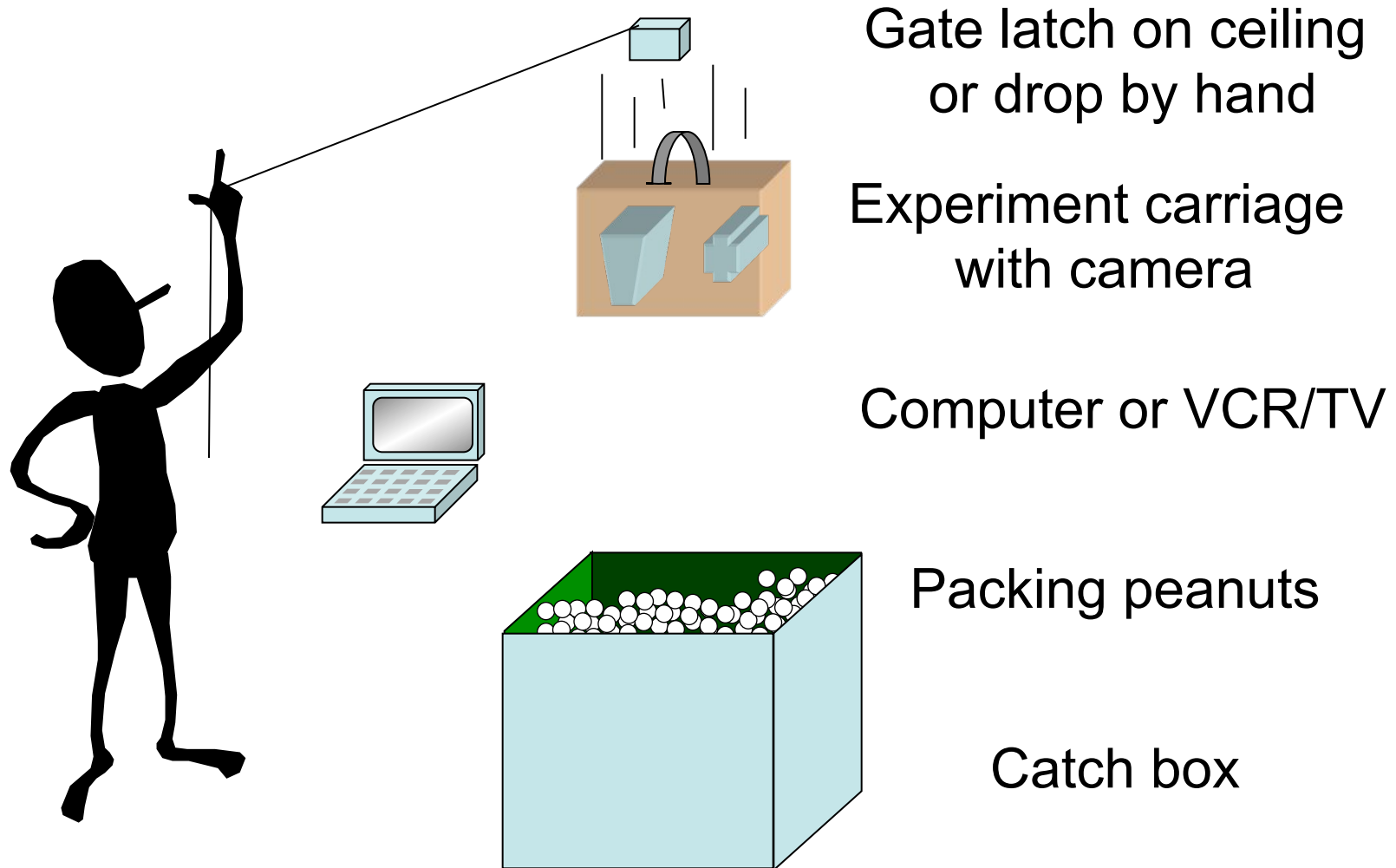
<http://tinyurl.com/MiniDrop-E> ←Experiments

- Wireless version

http://er.jsc.nasa.gov/seh/microgravity_drops.pdf



Classroom drop tower concept



More details and suggestions contained in teachers guides.

Summary

- Demonstrate microgravity in your classroom by dropping things!
- Assemble a kit of materials to demonstrate microgravity
- Consider making a mini-drop tower in your classroom for your student-created experiments

Further study!

- Students can use some of these topics to create science fair projects
 - *A Wisconsin middle school student did quite well in her science fair after she heard the leaky water bottle explanation. She built an entire science fair project based on a plastic bottle with a hole, and received a Superior!*
- Some students might be interested in a NASA microgravity aircraft ride when they are in college via NASA JSC's student program.
<http://microgravityuniversity.jsc.nasa.gov/>
- Or other programs
<http://www.nasa.gov/audience/forstudents/index.html>



Future Space Travelers

- Our astronauts that will go to the **moon** or an **asteroid** have probably just graduated from college.
- Another generation of NASA's astronauts are in your classrooms now!
 - They probably don't realize their destiny!
 - Imagine if someone had told a 12-year old Neil Armstrong that he would not only walk on the moon, but he would be the first human to do so!
- The engineers and scientists that will help make those missions happen are sitting at desks next to those future astronauts.
- Please continue to inspire and motivate our future astronauts, engineers, and scientists!

**Questions?
Comments?**

**Let's explore
microgravity!**



Questions later?

- Further information is available on-line
 - Session resources on-line here:
http://spaceflightsystems.grc.nasa.gov/DIME_Documents/SEEC/ug.html
 - Or simply: <http://tinyurl.com/ugSEEC>
- Questions about this material may be addressed to the authors:
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